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The Perception of the Vertical Dimension (3D) through the Lens of Different Stakeholders in the Property Market of China

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Abstract: China has experienced fast urbanization with a growing urban population, which has inevitably led to the adoption of a vertical housing style with high-rise buildings. However, how people subjectively perceive the vertical dimension (3D) in the property market is neither adequately documented nor well understood. The 3D perception helps us to understand a myriad of social and psychological effects of living in high-rise buildings. We organized and conducted semi-structured expert interviews, focus groups, and the circulation and compilation of questionnaires in Xi'an, China, to investigate how different stakeholders in the property market perceive 3D. The results show that: (1) real estate developers do not adjust property prices for specific 3D factors, and the local government does not consider 3D in housing policies; (2) the current status of 3D modeling in Xi'an is still in the embryonic state; (3) 3D factors are highly valued by buyers but not well-understood by real estate developers and local government. In addition, 3D factors score higher than horizontal (2D) factors (1.12 to 0.88). Gender and age groups do not influence housing preferences concerning 2D and 3D factors. These findings provide valuable insights for real estate developers concerning pricing policies and the local government concerning housing policies. In the future, 3D perceptions and factors should be prioritized in order to improve urban infrastructure and ensure the increased availability of, and fair public access to welfare related to 3D in urban areas.

Keywords: 3D; property market; high-rise building; urban morphology; built environment

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1. Introduction

In the past two decades, the urban residential property market has been flourishing in China, featuring skyrocketing property prices in first- and second-tier cities and accelerated urbanization progress [1–3]. The influx of urban immigrants increases housing demands, while the local government controls residential land supply [4,5]. Therefore, there seem few choices but to build vertically [6,7]. High-rise buildings have become a predominant type and a means of providing affordable housing; thus, living dozens of meters above the ground, a so-called vertical housing lifestyle has become mainstream. In the Chinese context, high-rise buildings are constructed collectively by one real estate developer as gated communities, which have closed walls or fences, as well as gates or controlled entrances, isolated from the outside, accompanied by various living facilities, either inside or very close to the buildings, such as kindergarten, public playground, and convenience shops [8,9]. Such a residence is notably different from those seen in rural areas or in the past 20 years in urban areas, where buildings are sparsely distributed and usually have

no more than six stories. Therefore, 3D factors should be paid attention to in urban areas with increasing building density and height. For example, the sky view factor (SVF), i.e., the indicator representing the proportion of the sky visible from a particular observer location, has been well studied as a significant factor in urban heat island studies, impacts human behavior, thermal comfort, and space usage [10,11]. Fu et al. [12] confirmed the positive correlation of sky and building view indexes (SVI) with property prices in Beijing and Shanghai, two megacities in China. The results indicated people's preference for sky openness. Changes in the vertical dimension (3D) will be ongoing in future decades due to continuous construction; this fact necessitates shifting the overall perspective from horizontal (2D) to 3D. People are aware of the importance of 2D-based locational and environmental factors (e.g., accessibility and public facility support) to their quality of life; in contrast, how 3D factors influence daily life still needs to be explored. With the increasing number of high-rise buildings, different stakeholders, especially in the property market sector (e.g., buyers, local government, and real estate developers), should recognize the new role that 3D plays in the urban property market. It is a worthwhile research exercise to reveal any gaps and differences among their perspectives.

Literature on how different locational and environmental factors influence property prices in urban areas is well established. Lan et al. [13] reported that buyers were willing to pay a 4% premium to stay away from the haze. A negative link between noise level and property prices was confirmed in central, semi-central, and peripheral urban areas of Bari, Italy [14]. Rivers have a positive influence on price for their amenity value [15], while polluted rivers have a negative impact [16]. Premium education and close proximity to parks both exert positive external effects [17–19]. Instead of approaching buyers directly on their housing concerns, the abovementioned studies constructed different statistical models with multi-source data and inferred the influences of specific factors. There are studies investigating people's preferences in the property market [20,21], some constructed from residents' perspectives, e.g., the youth and the elderly [22,23]. Nevertheless, these studies did not focus on 3D factors in urban areas, and existing knowledge as to different stakeholders' perceptions on 3D also needs to be updated to be comprehensive. For instance, the SVF has a series of seminal social and psychological influences [24], of which the high-rise housing system in Singapore is a typical example, and where diverse concerns associated with the high-rise lifestyle have been discussed [25,26]. Such concerns, in other densely populated urban areas, deserve similar attention.

The current cognitive gap leaves us with questions about how buyers' preferences in relation to different price-influencing, 2D and 3D factors vary, and how real estate developers and local government treat 3D. Further, no sufficient qualitative evidence on the current development of 3D modeling technology exists from industry professionals' perspectives (e.g., real estate sales manager and architecture designer). Property is an important asset investment for Chinese families [27], and high-rise residential buildings have become a strong sense of being in people's daily lives, so it is critical to have update-to-date knowledge concerning how different stakeholders perceive 3D in urban areas where there are an increasing number of high-rise buildings. In summary, the research questions that we sought to answer through this study, included (1) What is the pricing policy of real estate developers and the housing policy of the local government? (2) What is the current status of 3D modeling for different stakeholders? and (3) What are buyers' preferences for high-rise residential buildings, and how do they perceive 3D factors? To ascertain the answers to these questions, we obtained the perspectives of various stakeholders on the current status of 3D modeling, including real estate developers with respect to pricing policies, the local government as regards housing policy, and buyers', to ascertain their personal preferences in high-rise buildings, all with an emphasis on the 3D aspect. We took the city of Xi'an, one of the most important cities in northwest China, as the study area. The contributions of this study are twofold: (1) investigating how different stakeholders in the property market treat 3D in their respective fields, (2) identifying buyers' preferences concerning 3D in high-rise buildings.

The rest of this paper is organized as follows. Section 2 introduces the study area and provides the general policy background, explaining the overarching methodology design. The main body of the paper provides a detailed analysis concerning the pricing policy of real estate developers and the housing policy of the local government (Section 3), the current status of 3D modeling in Xi'an (Section 4), and the questionnaire analysis (Section 5). This paper ends with a critical discussion of the main findings (Section 6) and a conclusion (Section 7).

2. Materials and Methods

2.1. Study Area

Xi'an, the Shaanxi Province capital, with over 3000 years of history, was chosen as the study area (Figure 1). It is located in the central Guanzhong Plain, covering 10,752 km^2 with 11 administrative districts and two counties. Xi'an is one of nine National Central Cities, indicating its important political and economic status in Northwest China [28]. To overcome the challenges of the aging society and to attract talent [29], Xi'an is the first among first- and second-tier cities to launch talent introduction policies [30]. These policies achieved remarkable success; the annual population growth was 6.6% between 2016 and 2018 and the permanent population reached 10.37 million by 2018 [31]. Followed by the skyrocketing population, the housing demand was invigorated, with an alarming appreciation in property values and the construction of a large number of new high-rise neighborhoods. According to data obtained from Beike, one of the largest online house rental platforms in China, the ratio of high-rise residential neighborhoods (floor number $\geq$ 30) to total residential neighborhoods in Xi'an, was 10.7%, which ranked X'ian fourth in China in terms of high-rise residential populations [32]. This makes Xi'an a fitting and typical example to use in our investigation of the influences associated with 3D urban living.

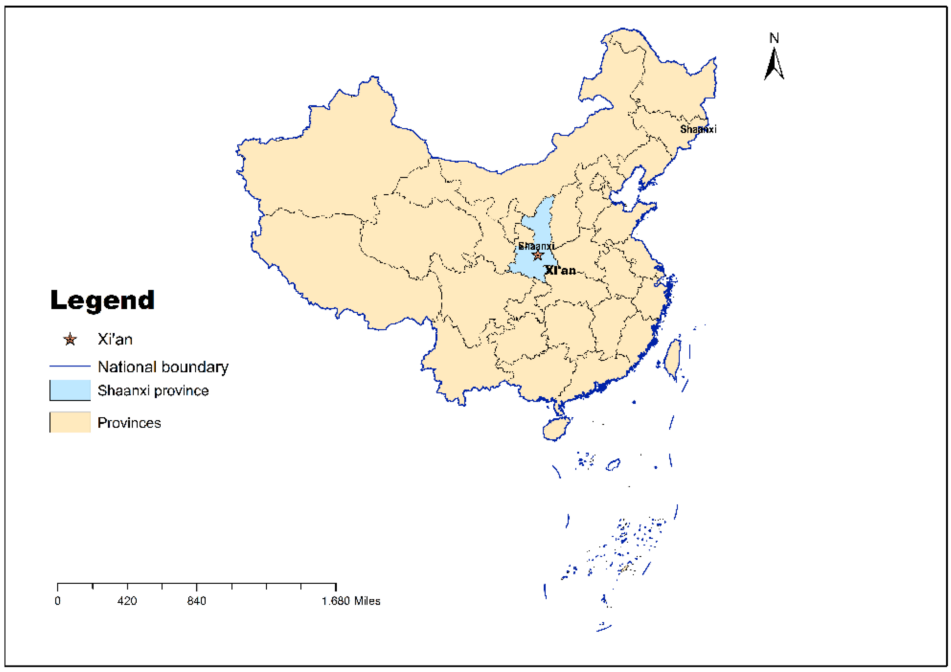


Figure 1. Study area map.

The Xi'an property market was temporarily restricted by two housing policies when our research was conducted, namely the purchase limit policy (PLP) and the fixed price policy (FPP) (PLP aims to control speculative purchasing for investment purposes and to satisfy real buyers' housing demands and living needs. For example, those who do not already own a residential property, enjoy purchasing priority, and the first-hand property

cannot be sold on the second-hand property market for five years. FPP aims to curb the soaring property prices). Under this policy, real estate developers do not have the right to determine the property price; instead, the price shall be approved by Price Bureau of Xi'an. If the price is considered too high, the permit shall not be issued.). These policies were implemented to ensure the price stability of the property market since 2018 [31]. One significant feature was that real estate developers had to propose prices to the Price Bureau, a single local governmental body, and ask for approval rather than set prices by themselves, i.e., the developers could not freely decide sales prices.

This research focuses on high-rise residential neighborhoods alone, which are generally designed for the middle-income group, not for well-off or low-income groups; therefore, the target population covers the masses. Figure 2 shows an illustrative model of a typical high-rise residential neighborhood in Xi'an. Property refers to one apartment or unit in one story of one high-rise building, and a story contains several properties. The property price refers to the first-hand transaction market price ((CNY)/m^2).

Figure 2. The illustration 3D sandbox model of a high-rise residential neighborhood in Xi'an.

2.2. Research Design and Data Preparation

To procure the opinions of different stakeholders comprehensively and efficiently, three groups were defined: (1) *real estate developer* (developer, for short, hereinafter), who is responsible for the high-rise building's neighborhood construction and sales and who plays the producer role; (2) *home buyer* (the buyer, for short, hereinafter), who intends to purchase a property in the building and who plays the consumer role; and (3) *Xi'an local government* (government, for short, hereinafter), who is responsible for the establishment and implementation of housing policy, and for property market management. Thus, the government plays the third-party regulator role. It is worth noting that the authors did not manage to reach government officials during their fieldwork due to the sensitivity of this research topic. Therefore, we re-directed our inquiries to the government-related institutions for the following reasons. First, they cooperate closely with the government regarding different projects (e.g., surveying, civil engineering, and property valuation). Second, they understand the government's policies very well because they are state-owned, rather than private companies. Third, we kindly asked them to take on the role of the government and to provide answers in the government's stead. Thus, they were able to provide sufficiently government-alike viewpoints. The institutions' names have been kept confidential, in accordance with the agreements we entered into with them, to secure their cooperation.

Semi-structured expert interviews, focus groups, and questionnaires were organized in October 2018 for primary data collection. The first two processes served as qualitative methods, and the questionnaire collected quantitative data. The personal information of all respondents was kept confidential. A gender and age balance was reached as far as possible to gain a neutral perspective. Interviews and focus groups were audio-recorded and interpreted using ATLAS.ti 8 [33], a robust software suitable for computer-assisted qualitative analysis. In ATLAS.ti 8, we used keywords as codes to rigorously construct links among different factors and meticulously interpreted transcripts [34]. The questionnaire's online distribution and statistical analysis were accomplished using Wenjuanxing [35], a Chinese online survey software widely used in academia and business. Secondary data, including property market-related policies, housing regulations, and local news reports, were used for background knowledge. The expected outcome was an in-depth understanding of local housing policies and the property market, which would avail primary data collection (Sections 3 and 4).

2.3. Semi-Structured Expert Interviews and Focus Groups

The selection criteria for respondents were quality and diversity rather than quantity. As the research focused on the 3D topic, we selected key experts with respective expertise and local citizens representing different types of bias and diverse perspectives. Access to respondents came from our local networks so that the quality of interviews and focus groups could be guaranteed. In total, eight face-to-face interviews with 12 respondents covering real estate developers and government-related institutions were conducted. The flexibility of semi-structured interviews allows for interrogation of the respondents' opinions and ensures the best use of respective professional knowledge [34]. Our aim was to reach a deep level of understanding and to encourage active discussions on specific topics, with different stakeholders, based on the interview guides. The expected outcomes were a list of factors positively/negatively influencing property prices, an overview of the pricing policy of developers, and the housing policy of the local government regarding 3D. All interviews were organized in cozy and quiet environmental settings. The key questions in the interview guide were pre-designed, tested, and revised before the fieldwork took place. The duration of the interviews ranged from 30 min to 1.5 h.

In total, two focus group discussions with seven respondents altogether were organized. The focus group discussions provided abundant information on diverse perspectives and feelings from respondents towards specific issues via group interactions in a relatively short time range [36]. As such, it encouraged buyers to reveal more about their preferences

for high-rise buildings in terms of 2D and 3D factors. The respondents were selected through our local networks. They were of different genders, age cohorts, and backgrounds to ensure diversity and avoid bias. The expected outcomes included the subjective reflections toward different 2D and 3D factors and living experiences in high-rise buildings.

The details of respondents can be found in Appendix A (Tables A1 and A2). The interview guides for the experts in the semi-structured interviews and for the respondents in the focus groups can be found in Appendices B and C. The results of our fieldwork were used to form Sections 3 and 4.

2.4. Questionnaire (Paper-Based and Online)

The questionnaire was designed to investigate buyers' preferences for different price-influencing factors, both 2D and 3D (i.e., where buyers prefer to live/buy). Existing housing studies and the knowledge obtained in interviews and focus groups helped with the questionnaire design [17,37,38]. The target population was Xi'an residents who can legally be active and purchase within the property market; therefore, we set the age range between 18 and 57. In China, the age of 18 is defined as an adult with full capability for civil conduct, and the age of 57 is the average retirement age (male is 60 and female is 55) [39]. We distributed the questionnaire online and in paper form, employing a random sampling strategy for its efficiency. Respondents signed an information leaflet and a consent form to ensure the research context and the implications of participation were correctly understood. As this research focuses on the perceptions of locals, rather than a global perception, we set up the Wenjuanxing software to automatically select the responses from responders with Internet Protocol (IP) addresses in Xi'an and within the appropriate age range. The paper-based version of the questionnaire was equally distributed in public spaces (e.g., main street, shopping mall, sports center) in Yanta, Lianhu, Qujiang New, Beilin, and Xincheng districts. Yanta district contains several of the biggest shopping malls in Xi'an and has great passenger flows. Qujiang New district is the first national cultural industry plot and an economic center with arts, premium high-rise residences, and tourism. The Lianhu, Beilin, and Xincheng districts are downtown areas close to the center of Xi'an. A total of 142 responses were confirmed valid within a one-week collection period. Because answering each question was not mandatory, there were empty answers, which were excluded from the analysis. The expected outcomes were a comprehensive quantitative analysis of buyers' preferences covering both 2D and 3D factors (Section 5). Below are six questions listed in the questionnaire and the full template, in English, is attached in Appendix D.

- Question 1: investigates the respondents' preferred story level. Three options are given, including the low story level (1st–10th), middle story level (11th–20th), and high story level (21st–30th). A high-rise building with 30 stories is used as a typical example, in a high-rise neighborhood. The respondents are asked to indicate their reasons.
- Question 2: investigates the respondents' preferences for various locational and environmental factors (both 2D and 3D) on a five-point Likert scale (a single choice), namely, not important at all (−2), not important (−1), Undecided/I don't care (0), important (1), and very important (2).
- Question 3: the respondents are asked for preferred property orientation (a single choice), for which the major rooms' (main bedroom and living room) orientation is taken as a proxy. In Chinese culture, these rooms are regarded as the most important rooms in properties within high-rise buildings. The respondent's reasons should be given.
- Question 4: continues, based on question 3, and asks about their willingness to pay (WTP) for preferred orientation (a single choice). The spillover amount is the ratio of the extra amount to the total property price. The currency is the Chinese Yuan (CNY).
- Similarly, Questions 5 and 6, investigate the preferences and WTP for specific view types (multiple choices).

3. Knowledge from Developers and Local Government

3.1. The Pricing Workflow of Developers

In urban China, the land parcel is bought and developed as a residential neighborhood by one developer responsible for the subsequent construction, sale, and maintenance [2]. The developer adopts the cost method, which adds up the total cost (e.g., the land transfer fee, development cost, marketing cost) at each stage and the expected yields. After the government releases information about the auction of land parcels, the developer's internal workflow starts as follows: (1) a customer analysis and cost-benefit analysis are executed by consulting and finance departments to estimate expected yields, (2) the engineering department devises a general architecture design, such as arranging floor plans of different property sizes, (3) the marketing department covers product positioning, targeted customer positioning, price modeling based on the local property market and buyers' expectations, and interpreting governmental policies, (4) the price is reviewed again by the finance department. If a specific threshold of yields (generally 8%) is expected, the land parcel bidding is approved. This cost review repeats at different stages for precise cost control. Following this, the price list, refined for each property, is proposed to the Price Bureau of Xi'an for final approval. In summation, developers do not adjust the property price specifically for 3D factors.

3.2. The Housing Policy of the Local Government

As stated above, after developers propose prices, the Price Bureau makes decisions by comparing the prices of similar neighborhoods. That is to say, the price is not broken down into certain details, it is only examined by the numbers. As mentioned before (Section 2.1), two important housing policies on a relatively macro level were established to stabilize the property market, and they have achieved the expected goal of stabilizing the property market. However, the local government has not yet included anything related to 3D factors and 3D modeling technology in their housing policy.

3.3. The Factors behind the Price Variation

Factors influencing price, positively or negatively, referred to in interviews and focus groups are listed in Tables 1 and 2. It is worth noting that some factors have two sides (e.g., although the properties with a high story level have a wider view, they are subject to wind and road noise). In general, properties at the middle story level are the most expensive; then, prices decrease as the stories go either higher or lower in a spindle-shaped tendency. There are no fixed formulas or models where a specific factor represents a specific amount of money. The price basis is set by comparing similar neighborhoods and the developer's expectation of the property market (e.g., whether it has an upward or downward tendency). The idea behind setting different prices is the developers' intention to sell out quickly and maximize profits. Generally, the price differential fluctuates between 10 and 40 CNY/m^2 per story (approximately 1.1–5.6 USD/m^2). Taking the average first-hand property price in Xi'an between April and October 2018 (11,000 CNY/m^2) as a basis, the differential is 0.1–0.4% of the total price [40]. Although this seems very small, it can be a considerable amount when added up. For instance, a property on the first story can be 1–4% cheaper than a property on the 10th story.

Table 1. An overview of the positive factors influencing property prices.

Name	Category	Reason	Note
High story level (approximately 25–30)	3D	Better privacy and broader vision.	
Low story level (approximately 1–4)	3D	Better living convenience, less noise, and less elevator waiting time.	The elderly can climb the stairs instead of waiting for the elevator.
All-facing-south orientation	3D	More daylight hours.	
South–north orientation	3D	More daylight hours and facilitates ventilation.	
Pre-decorated	/*	Saves time renovation time, especially popular among the youth.	
Green space/park/water	2D	Clear and broad vision, improved air quality, and less pollution.	
Historical site	2D	Better living experience.	
Safety	/	Better living experience.	Access control system, 24/7 security patrol, and fingerprint/face lock system.
Public sanitation	2D	Greater living comfort.	Regular cleaning in public areas.
Developer's reputation	/	Better credibility.	
Public transport/shop/restaurant	2D	Better living convenience.	
Hospital	2D	Medical care, especially for the elderly.	
Locations in the center of the neighborhood	2D	Convenient transportation, positive geomancy, and less external noise and pollution.	The central location reflects the Doctrine of the Mean (*zhongyong*) in Chinese.
Locations near good landscaping (e.g., man-made lake)	2D	Better view and living experience.	
Regional urban planning and development policy	/	Appreciation potential.	
Premium primary/secondary school district	2D	Enjoy exclusive educational resources.	Education quality is highly valued in Chinese culture.
Lucky numbers	/	Feng shui (geomancy)	The pronunciation of eight and six indicate prosperity and success.

* Means this factor does not belong to either the 2D or 3D category from a geographical and spatial perspective. For example, safety is an overall perception of public safety, and lucky numbers are based on culture and traditions.

Table 2. An overview of the negative factors influencing property prices.

Name	Category	Reason	Note
High story level (approximately 25–30)	3D	More wind and road noise, longer travelling time, and higher elevator fee and waiting time.	
Low story level (approximately 1–4)	3D	Possible high humidity and narrow field of vision due to architectural blocks (including the building itself) and tall trees.	

Table 2. *Cont.*

Name	Category	Reason	Note
Hetero-morphic architectural design	2D	Negative geomancy and inefficient space utilization.	Rooms in non-rectangular shapes and with exposed bearing pillars.
North orientation	3D	Fewer daylight hours and poorer ventilation.	
West orientation	3D	West exposure with higher room temperature in summer afternoons and greater electricity consumption.	
Main road inside the neighborhood/street/gate	2D	More noise and air pollution and negatively impacts the living experience.	
Garbage station/electrical power station/biogas digester/factory	2D	Possible stink, air pollution, and the noise of machines at night and bad views.	
Kindergarten, primary and secondary school	2D	More noise during the daytime.	
Historical site	2D	More noise during the daytime due to tourists and bad public sanitation if not well-maintained.	
Undeveloped area	2D	Potential safety risk and bad view.	Urban villages, wasteland, and rural-urban fringes.
Locations at the edges of the neighborhood	2D	Negative geomancy and longer travelling time.	
Close proximity between two buildings	2D	Depressed living comfort, narrow field of vision, and short daylight hours.	
Unlucky numbers	/	Negative geomancy.	For instance, the pronunciation of four is the same as death in Chinese.

4. Current Status of 3D Modeling in Xi'an

4.1. Real Estate Developers

Whereas 3D modeling is frequently applied in the architecture and landscape design of neighborhood construction, the predominant sales methods are still in 2D. The traditional sales office provides tools, including a 3D sandbox (Figure 2), floorplan, model room, and display area. The term 3D sandbox refers to a scaled-down model of the actual neighborhood development. Buyers can see a simulation of the whole neighborhood and the surrounding environment. The floorplan is a scaled-down map showing the relationship between rooms, spaces, and other physical features inside one property from a horizontal top view. The model room shows a furbished property example. The display area includes both a model room and landscape elements (e.g., grass, trees, and art installations). Virtual reality (VR) may be the most popular 3D application reported by real estate sales managers, and it has been utilized for landscape presentations in the first-tier cities (e.g., Shanghai and Beijing), but not yet in Xi'an. This is likely due to (1) the inherent time-consuming and labor-intensive nature of VR, which adds an unnecessary cost in a robust property market like Xi'an, and (2) customer feedback. Buyers are apt to believe what they see in reality rather than virtual models. The model room and display area are considered enough of a representation.

4.2. Home Buyers

Most of the respondents in our study only make use of 2D sale tools. They think the 3D sandbox and model room are intuitive enough and 3D modeling, as an auxiliary method, has both pros and cons. The pros are (1) intuitive representation since 3D visualization is easy to understand and aids with ironing out any confusion arising from abstract floor plans and (2) conduciveness to remote housing decisions. The cons are (1) questionable acceptance, for instance, the elderly may find it hard to accept new tools and (2) credibility. Whether a 3D model faithfully reflects reality remains unclear and is hard to verify.

4.3. Local Government (in Practice, from Government-Related Institutions)

To date, 3D models with full coverage and high resolution have not been employed in Xi'an. The main local governmental bodies working with 3D models are the Emergency Management Office and the Police Bureau. The former holds internal building structural models and is connected to the fire control department for emergency purposes. The latter is for public security, and the Police Bureau has exclusive access to these models. Currently, 3D models have not been used in the property market, and 3D factors have not been involved in framing housing policy. The ongoing challenges that prevent the use of 3D modeling include (1) a dearth of administrative efficiency. Necessary data are stored sparsely in different local governmental bodies. For example, the Housing Bureau has detailed building floor plans, and the Survey Bureau has large-scale survey data. Different bodies are not obliged to share data, (2) labor intensity. Automatic 3D modeling at a low level of detail (LoD) (e.g., LoD1, where buildings are visualized in simple blocks) is manageable, while manual intervention is mandatory for a high LoD. The landscape elements close to the ground (e.g., bushes, street lamps, and advertising boards) need to be reconstructed manually, (3) security. Making 3D models and relevant data open to the public is sensitive due to national security, and (4) high cost (e.g., regular 3D data updates and software development).

5. Questionnaire on Buyers' Preferences

5.1. The Story Levels

Out of 126 valid questionnaire responders, 22 chose the low story level, 54 chose the middle story level, and 50 opted for the high story level (Figure 3). The respondents who preferred middle and high story levels are almost equal (43% and 40%), and both outperformed those who voted for the low story level (17%). Thirty-one respondents explained their choice. Four wrote living convenience and one, acrophobia, for the low story level, in which elevator waiting time is reduced and for emergency circumstances (e.g., when they may be forced to use the stairs). Eleven indicated their reasons for choosing the middle story level, which can be categorized as the Doctrine of the Mean (*Zhong Yong* in Mandarin) and a broad field of vision. The former, which originated from Confucianism, aims to reach harmony both physically and mentally. Living in the middle, according to six respondents, signals a balance between living convenience, air quality, noise, and vision. Another five chose this level for the relatively good view and a broad field of vision. Fifteen chose the high story level mainly for the following three reasons, a broad field of vision without blocks, good view, and extended daylight hours. From the responses, we conclude that most respondents intend to live relatively distant from the ground.

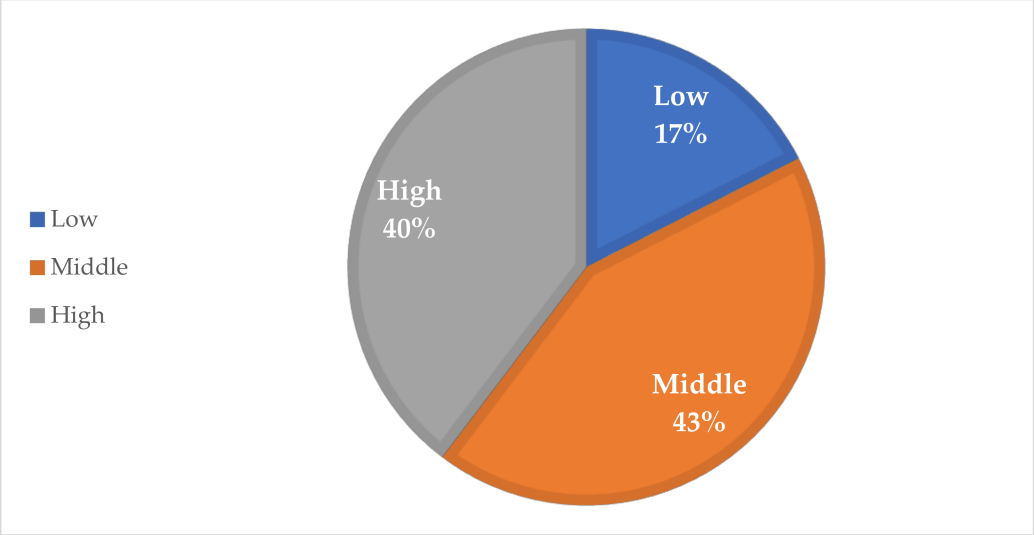


Figure 3. An overview of the preference for story levels.

5.2. Property Orientation

Out of 141 valid responses, only four choose options that are not of south–north orientation (Figure 4). Twelve respondents explained their reasons, and these respondents all choose the south–north orientation; seven mentioned good daylight, two aimed to avoid too much sunlight exposure, and four voted for ventilation. The results are consistent with the facts obtained in the interviews, confirming that most residents prefer the south–north orientation, which facilitates ventilation, cools down the room temperature in summers, and extends daylight hours. Only two respondents chose southwest–northwest and southeast–northeast. Deflection angles are not appreciated in housing selections within the Chinese culture. The due orientations (e.g., due north and due south) are more popular, which may be why almost all high-rise neighborhoods in the property market only have due orientations.

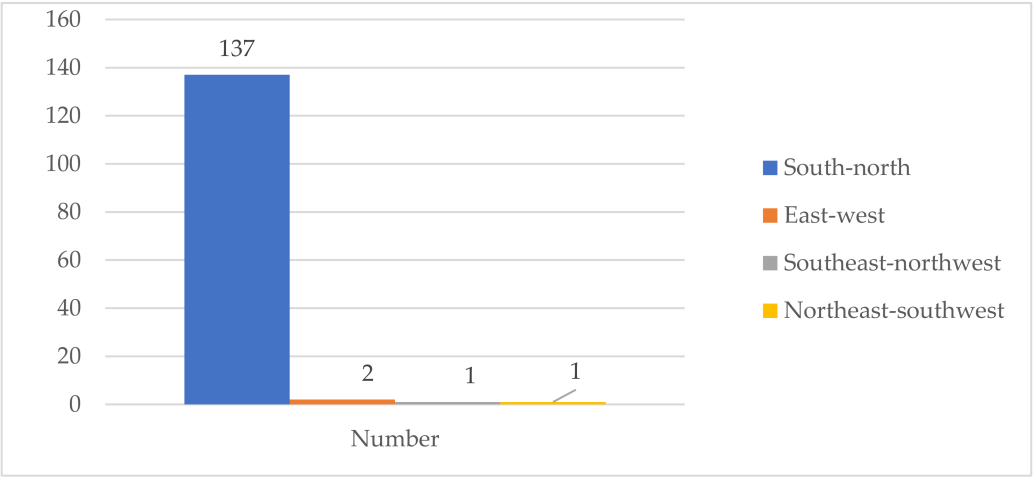


Figure 4. An overview of the preference for property orientation.

5.3. Environmental and Locational Factors (2D and 3D)

Figures 5 and 6 provide a detailed breakdown of buyers' preferences in respect of environmental and locational 2D and 3D factors, respectively. Regarding the 2D aspect, all respondents chose very important and important for public security, attaching significant importance to personal safety. Shopping and public transport were the following two top choices, with the supporting rate (the total of very important and important responses) of 82.4% and 70.7%, respectively. In the 18–27 and 28–37 age cohorts, the rates

were even higher, with 83.7% and 75.3%, respectively. This reflects that younger adults have more significant demands for shopping and public transport than other age cohorts. In addition, 69.7% of respondents regarded leisure as important and very important, 28.9% opted for undecided/I don't care while only two respondents thought it not important. Educational facilities were most popular among cohorts aged 28–37 and 38–47, with the supporting rate of 60.0% and 72.0%, respectively. A plausible reason for this is that they have higher possibilities of having young offspring than any other age cohort. As a result, neighborhoods with access to premium educational resources are highly valued. It is understandable that 53.3% of 18–27 years old are not concerned because they do not have to worry about children's education. By the same token, 68.9% of the 18–27 age cohort considered it important and very important to have easy access to food, while the rate dropped to only 50.0% in the cohort aged over 55. Only 6.4% of respondents voted either not important or undecided/I don't care in relation to sporting facilities. The cohort aged 38–47 valued sporting facilities most highly, with a supporting rate of 76.0; they valued physical health, and sports expenditure should be affordable. Entertainment facilities and cultural facilities were the two least important factors, with supporting rates lower than 50.0%. These two factors are also among the three factors which respondents selected as being not at all important. Of the respondents, 47.5% did not care at all about entertainment facilities, and 6.5% thought they are not important. For cultural facilities, only 41.3% had positive responses, and nearly half were not concerned. In summary, different age cohorts have different preferences in terms of locational factors.

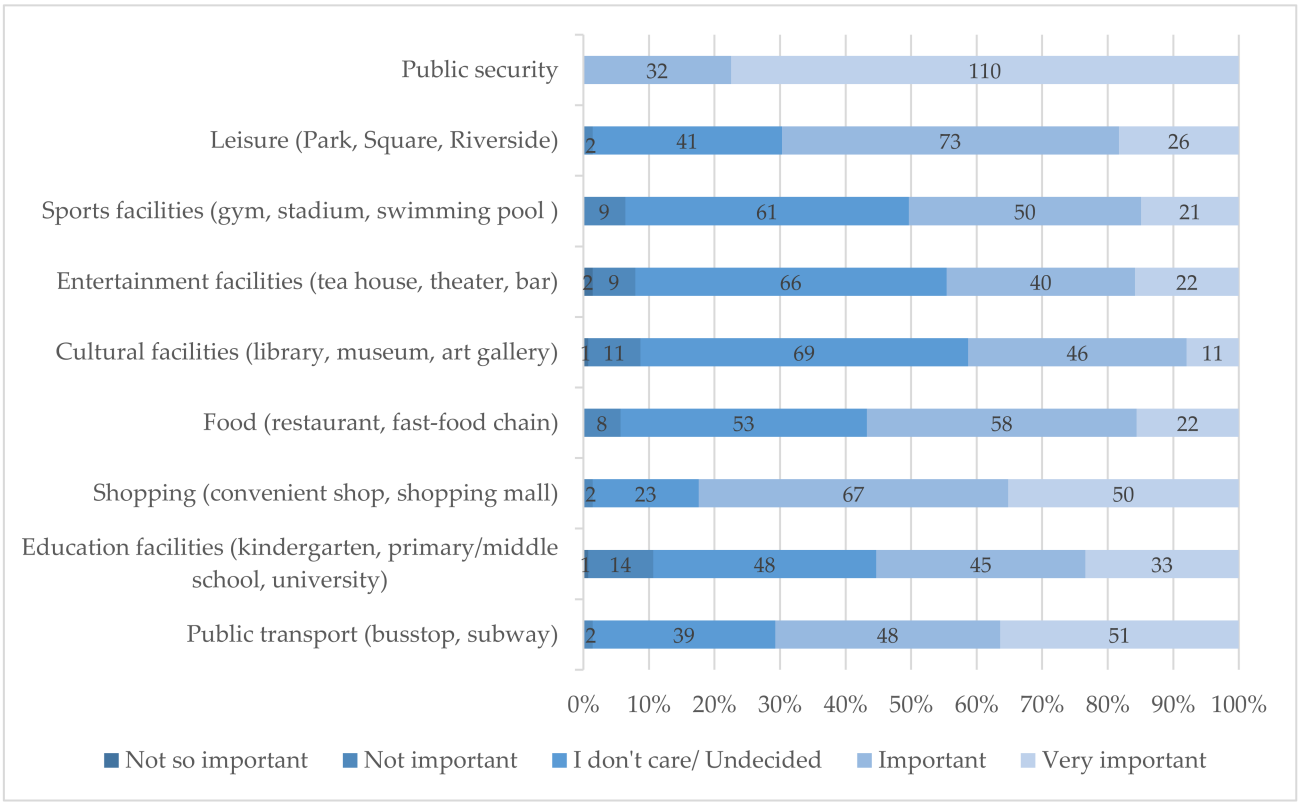


Figure 5. An overview of the preferences for 2D locational factors.

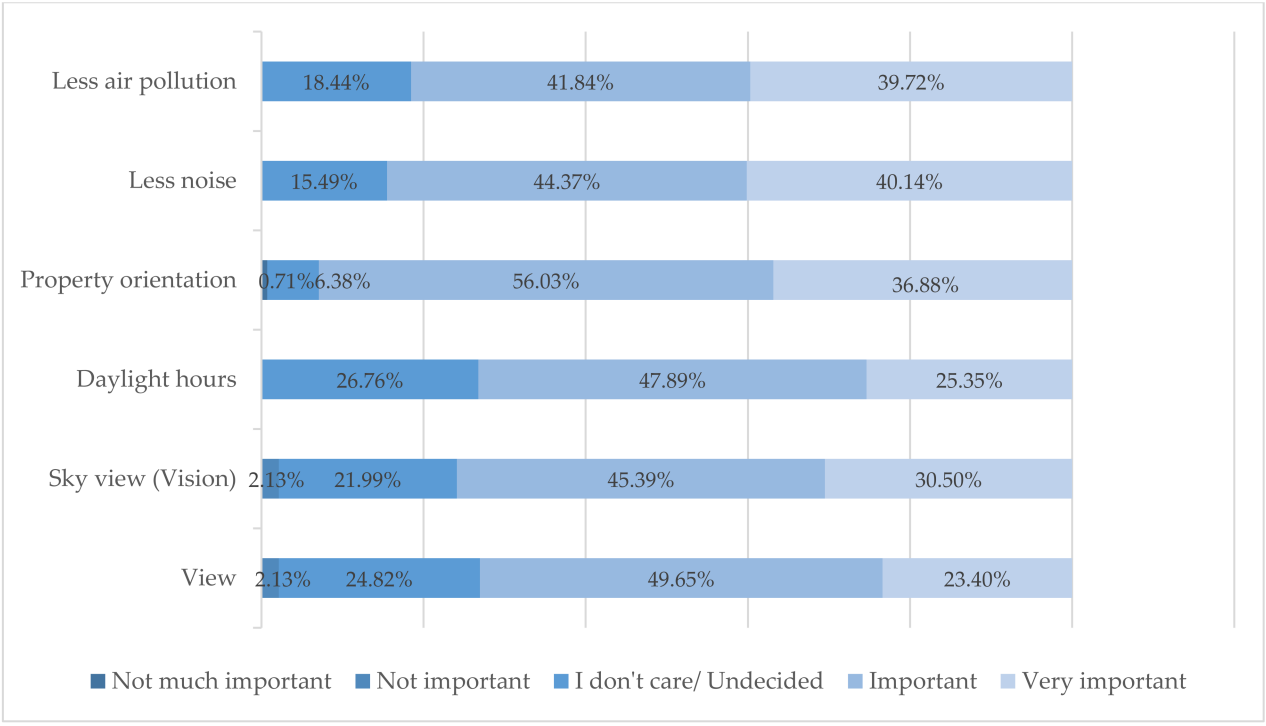


Figure 6. An overview of the preferences for 3D factors related to building height.

The results demonstrate that 3D factors, which change vertically with building height, have overall high support rates. This means that all age cohorts attach significant importance to 3D factors. The highest importance rating was property orientation, with a supporting rate of 92.9%. This factor significantly influences daily life and is within a controllable range for buyers compared to other factors (e.g., the view and the field of vision may change over time due to city development, but buyers can choose a permanent orientation). For a city facing fast urbanization and continuous construction, air quality and noise are always two critical issues and areas of concern for buyers. Less noise and less air pollution are the second and the third important factors, with a supporting rate of 84.5% and 81.6%, respectively. In their responses, no one opted for either not important or not very important in respect of these two factors (less noise and air quality). Different age cohorts also shared similar patterns for sky view (vision) and view, with supporting rates of 75.9% and 73.1%, respectively. Daylight hours received the highest rating of 26.8% for undecided/I don't care and the lowest rating of 25.4% for very important, which may be because the compulsory housing regulation ensures a minimum of two hours for direct sunlight at the winter solstice [41]. Therefore, buyers do not have to worry about daylight hours. As evidenced by the findings presented in this section, different age cohorts share similar preferences for 3D factors but different preferences for 2D factors.

Table 3 tabulates the final marks for buyers' preferences. The top three factors are public security, property orientation, and less noise. The lowest score is for sports facilities, entertainment facilities, and cultural facilities. On average, 2D factors have a score of 0.88, whereas 3D factors score significantly higher, with an average of 1.12. This indicates buyers appreciate and put a higher value on 3D factors.

Table 3. The final marks for locational and environmental factors (2D and 3D), (L—locational factors; E—environmental factors).

Factor	Category	Mark
Public security	2D, L	1.78
Property orientation	3D, E	1.25
Less noise	3D, E	1.25
Less air pollution	3D, E	1.20
Shopping	2D, L	1.17
Public transportation	2D, L	1.07
Sky view (vision)	3D, E	1.07
Daylight hours	3D, E	0.97
View	3D, E	0.97
Leisure	2D, L	0.85
Food	2D, L	0.69
Education facilities	2D, L	0.66
Sports facilities	2D, L	0.63
Entertainment facilities	2D, L	0.55
Cultural facilities	2D, L	0.43

Although our aim was to investigate overall housing preferences, we conducted a statistical analysis to investigate how 2D and 3D factors were perceived between genders and age groups. Student's *t*-test and ANOVA were employed in relation to gender and age groups, respectively. The results are shown in Table 4.

Table 4. The statistical analysis for gender and different age groups.

Factor	ANOVA-Age		Gender			
			Levene's Test for Equality of Variances		*t*-Test for Equality of Means	
	F	Sig	F	Sig	t	Sig
View	4.119	0.004 *	1.580	0.211	0.409	0.683
Vision	6.976	0.000 *	0.933	0.336	−0.429	0.669
Daylight hours	0.059	0.993	0.022	0.882	−0.552	0.582
Orientation	0.207	0.934	0.299	0.585	0.585	0.560
Less noise	1.345	0.257	1.373	0.243	−1.474	0.143
Less air pollution	1.249	0.294	0.986	0.322	−2.308	0.023
Public transportation	1.489	0.209	0.583	0.446	−0.276	0.783
Schools	2.421	0.052	0.726	0.396	−0.823	0.412
Shopping	2.546	0.043 *	0.079	0.780	−0.951	0.343
Food/restaurant	4.592	0.002 *	0.187	0.666	1.039	0.301
Cultural facilities	3.302	0.013 *	0.137	0.712	0.300	0.765
Entertainment facilities	4.111	0.004 *	1.533	0.218	0.195	0.846
Sports facilities	3.287	0.013 *	8.857	0.003*	−0.713	0.477
Leisure	1.680	0.159	0.152	0.697	0.400	0.690
Public security	2.853	0.026 *	49.337	0.000*	−3.476	0.001

*: significant at 0.05 level.

Regarding gender, two factors present with statistically significant differences, namely, sports facilities and public security, which are both 2D factors (Figure 7). Regarding sports facilities, the mean value for males and females is 0.57 and 0.67, respectively, which indicates females attach greater importance to sports facilities in their housing preferences than males. Similarly, public security had a mean value of 1.88 in females, whilst in males,

the mean value was 1.64. Regarding 3D factors, no statistically significant difference is detected in terms of gender preferences.

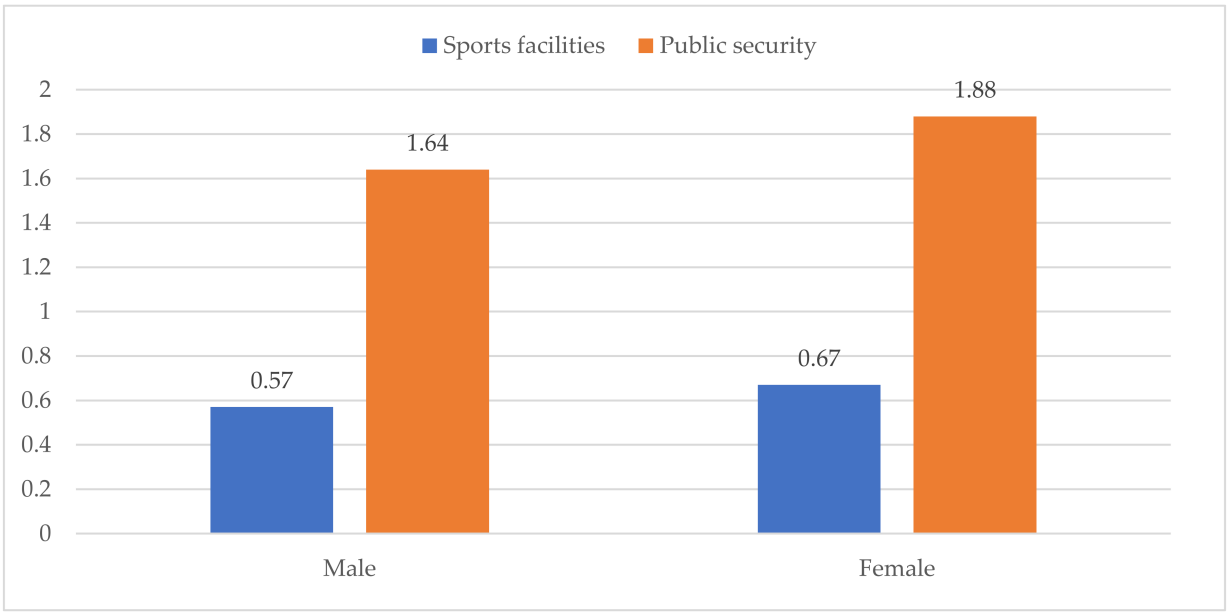
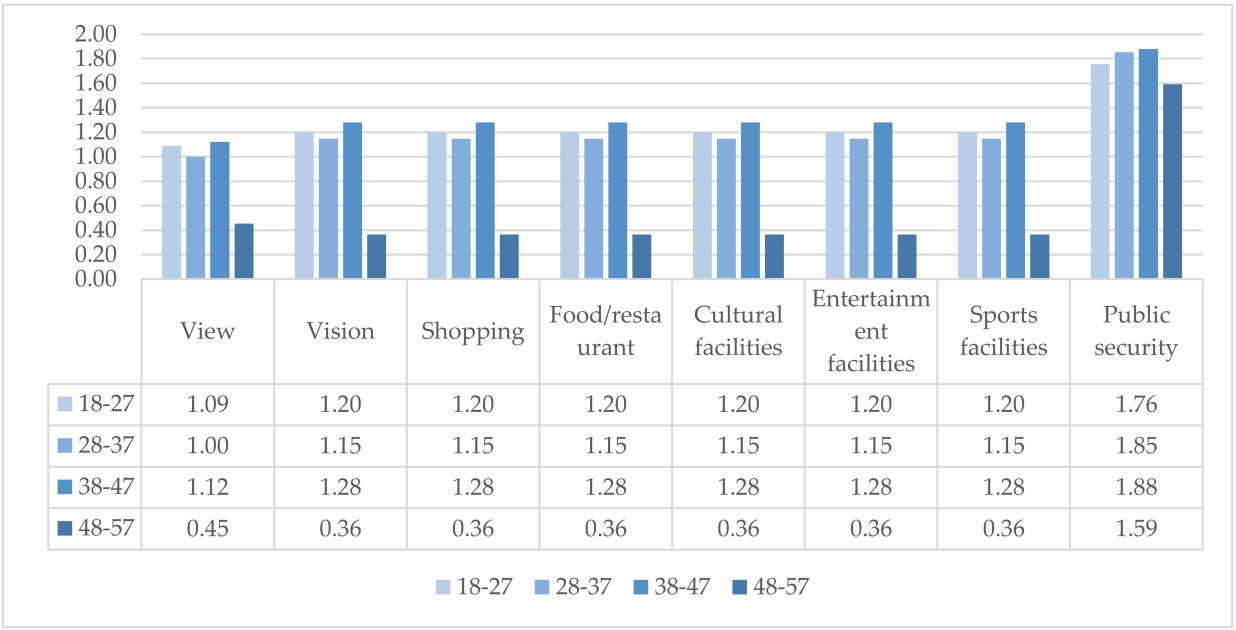


Figure 7. Differences in the mean values of 2D and 3D factors by gender (only statistically significant differences are shown).

Regarding age groups, view, vision, shopping, food/restaurant, cultural facilities, entertainment facilities, sports facilities, and public security—two 3D and six 2D factors, were observed, with a statistically significant difference among different age groups (Figure 8). Generally, the mean value of the age group 48–57 is considerably lower than the other three groups, whilst the other three groups have similar mean values. No significant differences between 2D and 3D factors were observed. These facts reveal that the elderly group cares less about the surrounding environment and infrastructure.



	View	Vision	Shopping	Food/restaurant	Cultural facilities	Entertainment facilities	Sports facilities	Public security
18-27	1.09	1.20	1.20	1.20	1.20	1.20	1.20	1.76
28-37	1.00	1.15	1.15	1.15	1.15	1.15	1.15	1.85
38-47	1.12	1.28	1.28	1.28	1.28	1.28	1.28	1.88
48-57	0.45	0.36	0.36	0.36	0.36	0.36	0.36	1.59

Figure 8. Differences in the mean values of 2D and 3D factors among different age groups (only statistically significant differences are shown).

5.4. View Types

Figure 9 shows the preferences for different view types. The majority did not prefer street/road (2.82%) and building (2.11%) views, and only 7 choose these two options. The other four view types were relatively popular. Ranked first, was a view of green land, for which 76.1% voted in favor. The second highest is views of parks and squares (54.2%). Green space positively impacts the environment, such as noise reduction and an improvement in air quality; parks and squares are always combined with delightful landscape designs. Additionally, being able to see a park means proximity to enjoy the convenience. In terms of views of the water and open spaces, 40.9% and 33.1%, respectively, found these favorable. This may be because water and open spaces have two sides. Apart from their aesthetic value, water quality may worsen and even become polluted without proper management, thereby negatively influencing the living environment. In addition, open spaces may become enclaves for sub-cultural groups without governance or high-rise buildings, which residents tend not to appreciate.

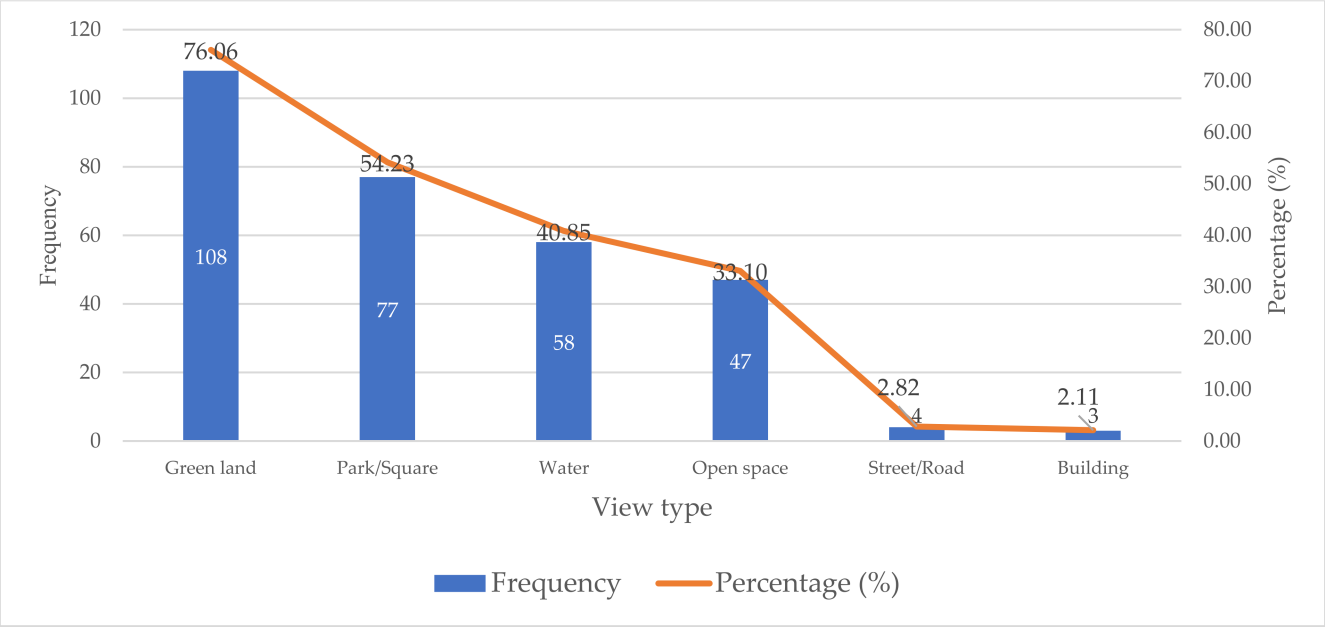


Figure 9. An overview of the preference for different view types.

5.5. WTP for View Types and Property Orientations

As shown in Table 5, 35.11% were willing to pay extra for views of green land, followed by 22.34% voting for views of parks and squares. Water and open space views have 19.9% and 14.9% support rates, respectively. Only 2.5% and 2.8% choose to pay extra for views of streets/roads and buildings, respectively, which partially explains why these are the two most unfavorable view types. Except for views of buildings, having only a 1.5% WTP, the mediums for the other five view types share the same WTP, of 5%. The average value of each view type fluctuates but with nuanced differences. A view of buildings has the lowest average rating at 2.75%, and one respondent even gave a negative rating of 5% for this view. Only seven respondents vote for views of streets/roads, and the average WTP is 5.3%. It is reasonable to assume that the affordable extra that buyers are willing to pay, is around 5% for each view type. These results are consistent with the knowledge obtained from the focus groups; which is that buyers prefer a lower price rather than paying more for the additional value of a view.

Table 5. An overview of WTP for different view types.

Name	Frequency	Percentage (%)	Medium (%)	Average (%)	Minimum (%)	Maximum (%)
Green land	99	35.11	5	4.91	0	30
Park/Square	63	22.34	5	6.91	2	50
Water	56	19.86	5	7.03	2	40
Open space	42	14.89	5	4.19	1	10
Street/Road	7	2.48	5	5.29	−5	20
Building	8	2.84	1.5	2.75	0	10

Regarding property orientation, 133 respondents chose a south–north orientation. Figure 10 shows the breakdown of WTP. Of the respondents, 87.2% have WTP $\leq$ 10%, and 67.7% of them have WTP $\leq$ 5%. The median of WTP for orientation is 5%, and the average is 7.5%. Thus, most people are willing to pay an extra 5%, based on total price, for a southern orientation, which means that a preferable orientation shares the same WTP value as favorable view types. As 5% is a moderate value, and WTP for view types and property orientations share a similar pattern, we conclude that buyers would prefer and choose a relatively low price than to pay a premium for perks.

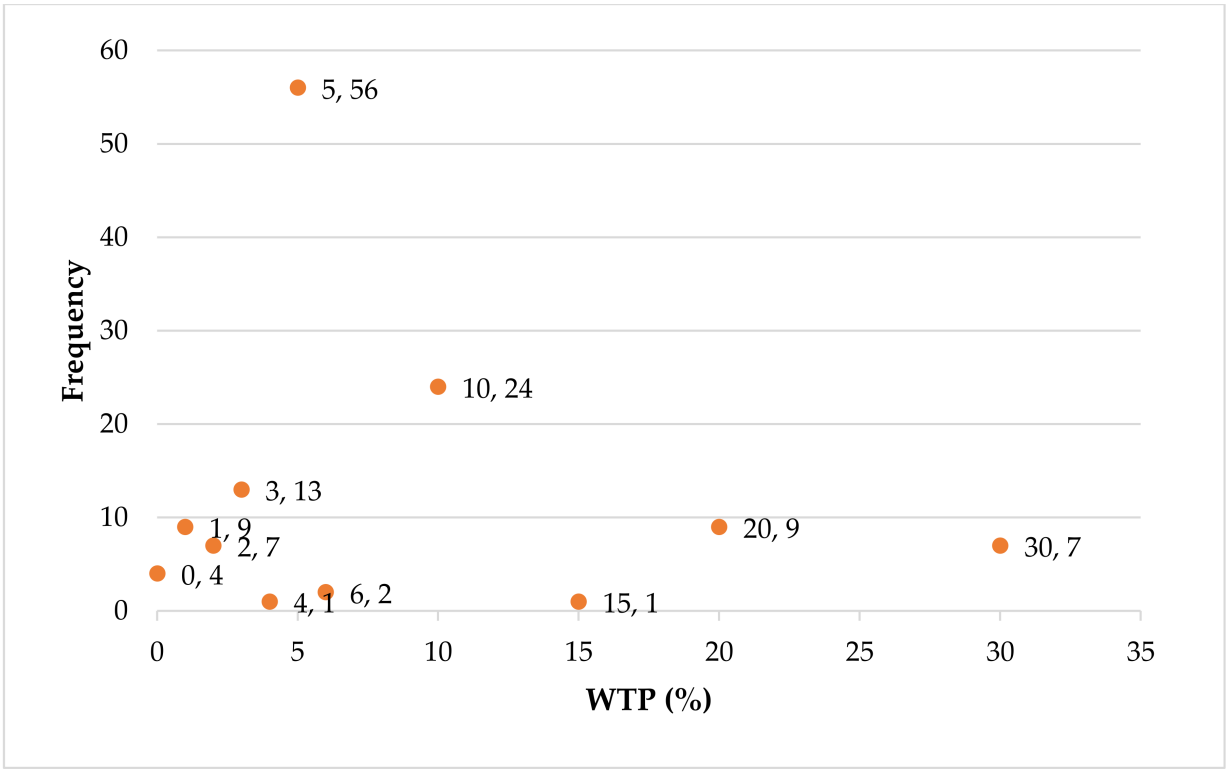


Figure 10. An overview of WTP for preferred property orientation. The *x*-axis represents the WTP (%), and the *y*-axis represents the number of responses (e.g., 5, 56 means 56 respondents are willing to pay 5% extra).

6. Discussion

China's fast-paced urbanization features a growing urban population, and it seems inevitable that urban areas will be built higher and higher due to limited residential land availability. The cities have become more vertical and complex over the past decades. The profound spatial changes and their influence on people's lives in the vertical dimension (3D), cannot be ignored. Moreover, 3D modeling has been proven to explain spatial

variations [42–44]. Thus, identifying the current status of 3D modeling and how different stakeholders perceive 3D in the property market is essential for a healthy property market and the development and promotion of urban well-being. This study sought to enhance our understanding of the role that 3D plays, and the influence it has, on different stakeholders in the urban property market, where there is an increasing number of high-rise buildings. The 3D factor has not been paid sufficient attention in the existing literature. Xi'an, one of the nine National Central Cities in China, with a population of over 10 million, is representative of Chinese-style urbanization, which is why it was selected as the study area.

Our study results reveal that specific adjustments for 3D factors do not currently exist in the pricing policies of real estate developers or in the housing policy of local government. Similarly, no so-called formulas, i.e., specific factors representing specific amounts of money, are employed in price formulation. There are two plausible reasons for this lack (1) the value of 3D factors is not recognized yet and is not accounted for and (2) the developers have lower profit margins because of PLP and FPP; therefore, they may prioritize maximizing profits, rather than distinguishing between 2D and 3D factors and making fine-tuned price variations to align with buyers' 3D preferences, the latter of which is reported as unnecessary by developers.

There are mixed opinions as to whether 3D modeling can bring positive externalities to buyers and developers. In general, buyers and developers alike, hold a wait-and-see attitude towards the added value brought by 3D modeling and questions as to whether 3D visualization can faithfully reflect reality. The large immigrant population brought by the opening of the Hukou policy generates massive housing demands [30], which causes demand to outpace supply, making the property market a seller's market. Given this background, developers may have neither the impetus nor the need to advance new technologies, which partly explains their lack of motivation.

In contrast, respondents from government-related institutions hold a positive attitude towards promoting 3D modeling for its powerful spatial analysis capabilities, extensive functionality, and intuitive visualization properties, which avail themselves to urban planning projects. Given the exclusive access of local government, incomplete coverage, and low LoD of 3D models, the current status of 3D modeling in Xi'an is still in the embryonic stage.

As for buyers' preferences, first, 3D factors receive an overall higher score (1.12) than 2D factors (0.88), which means that buyers highly value 3D factors in housing selections. The importance of 3D factors is also reflected in the appreciation for living in middle and high story levels (83%); great views and a broad field of vision cannot be enjoyed at lower story levels. This is in line with findings in the existing literature which reports that view, visibility, and sunshine duration change with building height [45–48]. Second, apart from public security receiving the highest score, and consistent with common-sense intuition and Wu [23] as well, 3D factors are rated at the very top. This fact indicates that buyers value 3D factors to a significant degree. Noise levels are related to different story levels, and buildings close to roads are exposed to a higher noise level [47–50]. Air pollution also correlates with 3D; the pollutant concentration decreases as the building height increases [51,52]. This also has a close link with noise because high traffic flows are likely to cause low air quality [53].

We made several important findings regarding how different genders and age groups treat 2D and 3D factors. First, males and females generally agree and degrees on most factors, except for sports facilities and public security, which females attach higher importance to than males. On the one hand, it has been reported that women feel unsafe in different scenarios (e.g., during nighttime and on public transportation) [54,55], and they also tend to take fewer risks than men [56]. The large number of high-rise buildings in urban areas can cause poor visibility and light, darkness, and enclosed paths, which can be perceived as potential causes for alarm [57,58]. Therefore, the female group had higher requirements about public security. On the other hand, the growing demand for sports facilities by females may have two reasons, (1) women are more active which has caused a growing demand for sports facilities [59] and (2) women focus more on maintaining physical health

and have more strict body shape ideals than male [60]. Second, we found that the 48–57 age group has a lower mean value on 2D and 3D factors, i.e., they have lower expectations of the surrounding environment and infrastructure and have lower expectations of the living quality than younger groups. A possible reason for this could be that, compared to younger people, they engage in less social or outdoor activities and spend more time indoors, i.e., their life radius has shrunk; therefore, the influence of surrounding public facilities on their housing preferences is weakened. Finally, we conclude that gender and age groups do not influence buyers' housing preferences for 2D and 3D factors because no significant differences in the mean values of 2D and 3D factors were observed.

Nonetheless, implicit connections between 2D and 3D factors were noticed. Locations in the center of a neighborhood have a positive externality. This may be because of relatively distant proximity to roads/streets, and traffic noise and air pollution risks are considerably reduced. Therefore, 3D factors affect housing selections, even in the 2D aspect, when buyers are not self-aware. We also found that different age cohorts have different demands for 2D locational factors, a fact that is proven by existing literature [21,22,61]. Younger adults love entertainment facilities, while the middle-aged group emphasizes access to premium educational resources and sports facilities. Wu [23] reported educational facilities as one of the top five factors valued by young consumers, which is proven in this study that 28–37 age cohorts attach the most importance to education.

The limitation of this study lies in the nature of small-scale pilot studies. We used our local networks to offset the negative influence of a small sample collection, by approaching professionals directly, organizing active focus groups, and distributing questionnaires in downtown areas. This study applied both qualitative and quantitative data collection methods to capture a diverse spectrum of opinions in the Xi'an property market at a local scale. Due to time and cost limits, 142 responses to the questionnaire were eventually confirmed as valid. It would be preferable to have a larger sample size in future studies with more demographic data collected (e.g., in terms of income, educational background, job).

Future recommendations are presented from the perspectives of different stakeholders: (1) Real estate developer: More attention should be paid to 3D factors in price formulation. As Wen et al. [18] indicated, properties at lower story levels are differently affected by noise, ventilation, and sunlight. It is critical to investigate how 3D factors impact living quality. What kind of noise and at which time of the day troubles most? How does air quality change vertically? Empirical answers to such research questions can provide valuable lessons to optimize architectural and landscape design and pricing policy. (2) Home buyer: Revealing the importance of 3D can improve buyers' awareness of 3D factors in housing selections. As cities continue to become more compact and vertical, bringing 3D to the forefront will provide a new perspective in understanding its role in daily lives. Nevertheless, the inherent complex characteristics of a 3D built environment are challenging to be understood if not appropriately visualized and analyzed. Moreover, it is difficult for buyers to obtain correct information about properties, and the developers always serve as the only information provider, which may cause a certain degree of bias. A city digital twin, which is capable of visualization and spatial analysis, may be a solution to this problem. Existing open-source data (e.g., LoD 2 building models of The Netherlands [62]) can be used for scalable visualization, while high-resolution data and precise façade construction are not mandatorily required [63]. The ultimate goal is to provide basic visualization about the 3D built environment to help develop a helicopter view for buyers and thus, to some extent, offset the common information asymmetry in the property market. (3) Government: Future housing policy should better reflect the importance of 3D. First, fair access to sufficient daylight hours and broad sky vision is of critical value in urban areas, with increasing amounts of high-rise buildings because these factors highly relate to the general public's physical and mental health [64]. Second, from the gender perspective, urban infrastructure improvement is necessary to maintain public security (e.g., proper urban landscape design to increase women's sense of security, thus avoiding potential crimes) and improve living quality (e.g., create more public spaces for fitness exercises, with

free access). Third, an uneven distribution of 3D benefits may create new socio-spatial inequality, mainly influencing low-income groups who can rarely afford housing. In China, the property tax reform (e.g., evaluation criteria for 3D factors to serve as part of the tax basis) which has been implemented in pilot form in Shanghai and Chongqing and will be extended nationwide in the future, which can be helpful to ensure fair access to 3D [65]. (4) Researcher: We advise categorizing the visual qualities in further detail by developing an index of quality evaluation, either qualitatively or quantitatively, or both. For example, identifying and categorizing the specific contexts of view types is important to determine their aesthetic value (e.g., lawns, grassland, and forests are all green, but are they the same in practice, and which type do people appreciate most?).

Moreover, as this study was conducted before the COVID-19 pandemic [66], it would be of practical importance to conduct a comparative study to see whether buyers have changed their preferences in pandemic times. Since people are forced to work from home and to reduce social interactions, psychological disorders (e.g., depression and anxiety) are found to increase to a large extent, especially in vulnerable groups [67]. As evidenced by existing literature, the design of high-rise residences brings with it, psychological consequences [68]. The impact of 3D factors can be magnified or become patently obvious as a result of extended time spent in home offices, in high-rise residential buildings. For example, a broad sea view can have a positive psychological impact. Living in a property close to a road with worse air quality and more noise can have a negative psychological impact. Gifford [24] suggested that high-rise residence was less satisfactory than other housing options, and has this become worse or better as a result of the COVID-19 pandemic? There have been abundant studies investigating how to create an anti-virus environment in high-rise buildings for public health control purposes [69,70]; however, to the best of the authors' knowledge, no studies have investigated the connection between 3D factors and residents' psychological conditions in high-rise buildings and how they may change before and post the COVID 19 pandemic. The results of this study provide valuable data for optimizing high-rise residence design and maintaining the city's sustainability and people's mental health.

7. Conclusions

While the vertical dimension (3D) of the constructed environment has fascinated many and has resulted in many technical advances produced by those dedicated to solving problems arising from urbanization, how different stakeholders in the property market perceive 3D continues to receive insufficient attention. The originality of this article is threefold, in that (1) it takes Xi'an, one of the nine National Central Cities in China, as a typical example of a complex urban area, with increasing amounts of high-rise buildings, (2) it is the first study to investigate buyers' housing preferences with an emphasis on the 3D aspect, and (3) it comprehensively elucidates and evaluates the different ways in which stakeholders perceive 3D in the property market, through semi-structured expert interviews, focus groups, and questionnaires. To answer the primary research questions, we cover the pricing policy of real estate developers and the housing policy of local government, the current status of 3D modeling in Xi'an, and buyers' preferences, emphasizing the 3D aspect. We identify the pricing policy of developers and find that specific adjustments for 3D factors currently do not exist; moreover, the local government also does not consider 3D in their housing policy. We reveal that the current status of 3D modeling in Xi'an is still in the embryonic stage. There exists a cognitive gap regarding 3D among the consumer (home buyers), producer (real estate developers), and the third-party regulator (the local government); buyers highly value 3D factors, while 3D factors do not receive enough attention in the pricing policy of developers nor are they reflected appropriately in the housing policies of the local government. The highlights of the questionnaire results lie in the fact that different age cohorts and genders have distinct preferences while they do not treat 2D and 3D factors differently. Women care more about sports facilities and public security in their housing selections, and the elderly group has lower

expectations with regard to both 2D and 3D factors. These findings are expected to provide valuable insights for future policy-making in two regards (1) reshaping housing policy with added 3D information to compliment the recent high-rise development in urban areas, especially with regard to the aspect of urban infrastructure that serves to guarantee women's sense of security. Under COVID-19 pandemic conditions, the sustainability and living quality of high-rise buildings should be cautiously evaluated as it can significantly impact the residents' psychological conditions and (2) shift land administration toward a more humanistic approach, to engender urban well-being. Specifically, the benefits of 3D should be equally shared and accessed by the public in general, rather than as a matter of privilege. It would be of value to explore the nexus of how 3D modeling, a technical method, can make the vertical dimension more easily and explicitly visualizable and understandable by the general public in the future.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. The Background Information of Respondents

The name of government-related institutions are protected by confidentiality agreements between the authors and the respondents.

Table A1. The overview of semi-structured expert interviews.

	Respondents	Institution/Position	Contexts
1	Two males	Government-related institution A/Engineer	Current status of 3D modelling related to the property market in Xi'an; land use distribution; Xi'an housing policy.
2	One male and one female	Developer A/Architecture and landscape designer	General pricing policy; the role of 3D factors in the architecture; buyers' preferences.

Table A1. *Cont.*

	Respondents	Institution/Position	Contexts
3	Two males	Developer B/sales manager	General pricing policy; buyers' preferences; the roles of 3D factors in the property price; the current status of 3D modelling in Xi'an.
4	One female	Developer C/sales manager	General pricing policy; buyers' preferences; the roles of 3D factors in the property price; the current status of 3D modelling in Xi'an.
5	One male	Developer D/landscape designer	The balance between landscape and budget; landscape design; buyers' preferences on different views.
6	One female	Developer E/sales manager	General pricing policy; buyers' preferences; the roles of 3D factors in the property price; current status of 3D modelling in Xi'an.
7	One male	University/associate professor	The future trend for property valuation; 3D modelling in valuation and its ongoing challenges; the reasons for property price increase in Xi'an.
8	Two males	Government-related institution B/manager	The reasons for increasing property and land price in Xi'an; 3D modelling in urban planning.

Table A2. The overview of focus groups.

	Respondents	Purchase Experience	Background
1	Two senior and one young male	They all have experience in housing purchase.	Two have jobs (bachelor degree), and one is retired (technical secondary school).
2	Four young females	One has purchase experience, two rents, and one lives with parents.	All hold bachelor degrees and have jobs.

Appendix B. The Interview Guides for Experts in Semi-Structured Interviews

The following questions are key questions used in different interviews to lead the whole interview process as interviewees held different expertise; the actual questioning might be different depending on interviewees 'responses and attitudes.

1# Interview guide for the architectural designer

- What is your general architecture design principles for high-rise apartments?
- Does the architecture plan affect the property price in certain scenarios?
- What is the price difference between the price developers report for approval and the final price approved by the Price Bureau of Xi'an?
- Which type of residence is most popular based on your experience? What are the common attributes of them?
- Which administrative districts are popular for residence selection?
- Do you think the preferences of buyers for residence has changed in time?
- Do you think buyers will pay more for a better view?

- Do you have 3D models for buyers at the sales office? What software do you use to create them? What is the cost of finance and time?
- Do you think interactive 3D models can improve the performance or better communicate with buyers? Is it necessary?
- What do you think is the main factor causing the huge property price growth in the past two years in Xi'an?
- What is your general price-making policy?
- Is the price influenced by view/environment/skyline, etc.?
- The price of different storeys in one building is different. What is the price difference and how you determine it? Do you adjust the price of some specific storey?
- What are the main considerations when designing the landscape inside the neighbourhood? What are the indicators that buyers value?
- How do you optimise the distribution of the apartments limited by floor area ratio to reach the best vision or daylight?

2# Interview guide for the landscape designer

- What kind of view do the buyers like? Do they value the view?
- Does the housing preference of buyers change over time?
- What role does the landscape play? How do the real estate developers balance the relationship between cost and price?
- What are the main steps of the landscape design for a neighbourhood?
- Do you use 3D models for landscape design?
- What are the main contexts do you value in landscape design?
- How does the landscape balance functionality and aesthetics?

3# Interview guide for the sales managers of the real estate developers

- Which type of residence is the most popular based on your experience? What are the common attributes of them?
- Do you think that the preferences of buyers for residence has changed in time?
- In your experience, which indicators do buyers consider when buying an apartment?
- What is your general price-making policy? What are the main steps/procedures and what method/technique is used?
- What influence does fixed-price policy have on your pricing policy?
- How do you determine the price difference between different storeys? Which indicators are important?
- What are the living experiences for apartments on different storey levels?
- Do you have some certain algorithm to calculate the price difference of the apartments on different storey levels?
- How do you handle the supporting facilities around the neighbourhood? Is it possible to have a situation where the facilities cannot keep the pace with the neighbourhood construction?
- Have you ever used a 3D model at the sales office to the customers? What is the customers' feedback?
- Does the 3D model help you better sell the properties? Is it necessary? Why?
- What is the price difference among each administrative district in Xi'an? What is the main reason causing this kind of difference?
- What do you think is the main indicator causing the huge property price growth in the past two years in Xi'an?

4# Interview guide for the university professor in Chang'an University

- Would you please briefly introduce us about the knowledge of the land valuation?
- What do you think of the role of 3D modeling in property valuation?
- Which indicators do you think promote the land parcel price and the property price in Xi'an?

- Is the scope of property registration still determined according to the 2D floor plan? Does it contain 3D information?
- Have you ever used 3D data in land valuation? Why?
- Do you think it is necessary to include 3D data into the land valuation?
- Is there any difficulty in data acquisition or administration when using 3D data or building a 3D system?
- In your opinion, what can be improved or added to the current land/property valuation framework?

5# Interview guide for the valuation & consult company

Section 1: Land Price & Residential Property Price

- What do you think is the main indicator causing the huge property price growth in the past two years in Xi'an?
- What is the main reason causing the land parcel price growth in Xi'an?
- How does the Price Bureau of Xi'an approve the property price under the fixed-price policy?
- The population growth in Xi'an has caused a huge pressure on the housing. What are the current countermeasures taken by the government? How effective is it? How long will this situation be expected to last?
- The unbalanced supply-demand relationship in the first-hand property market has also contributed to the active second-hand market. How does the government view the phenomenon of the reverse price of second-hand property prices? Is there already a prepared policy for this phenomenon?
- When selling the land parcels to the real estate developers, there will be a series of limited indicators (such as floor area ratio). How does the Xi'an government set these indicators? How to supervise in the construction process?

Section 2: Urban Planning

- What is the city orientation of Xi'an at past and in future in perspective of urban planning?
- What indicators are specifically considered for construction land planning? What is the reference to the quantity of new construction land?
- Why does the Xi'an municipal government open the Hukou policy?
- In your opinion, in addition to population growth, what other indicators have contributed to the property price growth in Xi'an?
- How do property price and urban planning affect each other?
- How does urban planning intend to keep up infrastructure construction with huge population growth?
- What is the future development orientation of the different administrative districts in Xi'an? How does the government allocate the resources?
- Have you ever considered the development of the city in terms of height in the planning?
- What is the application status of 3D technology in the urban planning of Xi'an? In your opinion, what can be the possible future application scenarios?

6# Interview guide for the Xi'an Survey and Mapping Institute

- What is the fixed-price policy in Xi'an residential property market?
- How does the Xi'an municipal government determine land use and sell residential land parcel?
- Which indicators will you take into consideration when making the residential land use planning? Which factors among them do you think will influence the property price?
- What kind of planning will influence property price? How does the government handle conflicts or problems?

- Do you use remote sensing data (e.g., satellite image, UAV, LiDAR) in the planning? Have you ever considered the 3D modelling part?
- What techniques do you use to build the 3D model?
- Do you take residential property price as an important indicator in the urban planning process?
- Which governmental department is responsible for determining the residential property price?
- In your opinion, what can be improved according to current property valuation procedure?
- Which indicators do you think caused the continuous rise in residential property prices in Xi'an in 2018?
- Do you think it will be helpful to consider the status and future development of the city in the vertical dimension during the planning process?
- Will Xi'an have such a large-scale 3D application for urban planning in the future? What problems will you face?
- What is the level of details (LoD) the current 3D model application has? What is the cost?

Appendix C. The Interview Guide for Focus Groups

- What do you think of the residential property price growth in Xi'an?
- What attributes do you value in a high-rise apartment? Why?
- What kind of apartment do you dislike? Why?
- Does your preference for housing change over time?
- In your opinion, what are the reasons behind the price difference of apartments on different storeys? What are the factors related to the height you value when buying an apartment?
- What kind of view do you most want to see/not want to see? Why?
- How much are you willing to pay for these apartments on different storeys? (Show pictures of the south-facing balconies of the apartments on different storeys)
- How much are you willing to pay for these different kinds of view? (Show pictures of different views, including green land, street, square)
- Have you experienced 3D technology during your purchase, such as VR? Do you think the existing sand table, model room, and display area are enough for you to understand the whole scenario? Is it necessary for a 3D model?
- In your opinion, what are the factors promoting the residential property price in Xi'an? What are your expectations for the future trend of Xi'an residential property prices?
- Have you ever had a problem with the real estate developers' description after you bought an apartment? What impact does it have? (Examples, supporting facilities are not perfect/slow, the unreasonable design of the apartment)
- Will the planning of Xi'an affect your housing choices? If so, what kind of planning will affect?
- In the future, if you do housing choice, which administrative district will you choose? Why?

Appendix D. The Questionnaire Template in English

Gender: ☐ Male ☐Female Age: ☐ 18-27 ☐ 28-37 ☐ 38-47 ☐48-57

1. Which storey level do you prefer in a high-rise apartment?

☐Low ☐ Middle ☐High

Why? _____

2. What indicators do you think are important in your housing decision? Please mark them in the following table.

	Very disagree	disagree	Undecided/I don't care	Agree	Very agree
View	○	○	○	○	○
Sky view (vision)	○	○	○	○	○
Daylight	○	○	○	○	○
Property orientation	○	○	○	○	○
Less noise	○	○	○	○	○
Less air pollution	○	○	○	○	○
Public transport (bus stop, subway station)	○	○	○	○	○
Education facility (kindergarten, primary/middle school, university)	○	○	○	○	○
Shopping (convenient shop, shopping mall)	○	○	○	○	○
Food (restaurant, fast-food chain)	○	○	○	○	○
Culture facility (library, museum, art gallery)	○	○	○	○	○
Entertainment facilities (tea house, theatre, bar)	○	○	○	○	○
Sports (gym, stadium, swimming pool)	○	○	○	○	○
Leisure (park, square, riverside)	○	○	○	○	○
Public safety	○	○	○	○	○

3. What is your preferred choice for the orientation of the major room (e.g., the main bedroom, living room)? (multiple choice)

☐South ☐ North ☐ East ☐ West ☐Southwest

☐Southeast ☐Northwest ☐Northeast Why? _____

4. What percentage of the total price are you willing to pay for your preferred orientation? (e.g., +5%, -10%)

_____

5. Which type of view do you prefer? (multiple choice)

☐Street ☐Open space ☐Green ☐Building ☐ Water ☐ Park

6. What percentage of the total price are you willing to pay in additional for a property having following view? (e.g., +5%, - 10%) (multiple choice)

☐Street_____☐Open space_____☐Park_____

☐Green_____☐Building_____☐ Lake_____☐ Tourist site_____

After I finish the research, may I invite you for a short feedback questionnaire to evaluate my 3D model? If you are willing to do, please leave your WeChat or email so that I can send you a questionnaire. It is voluntary and the information will be kept confidential and only for research purposes.

Email/WeChat/QQ:

Figure A1. The English version of questionnaire template (the original questionnaire is in Chinese).

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